APPENDIX F

PHYTOPLANKTON REFERENCE COMMUNITY DATA ANALYSES SUPPORTING CHLOROPHYLL *A* CRITERIA DERIVATION

This appendix describes various analyses performed with the 1985-1999 Chesapeake Bay Program water quality and plankton monitoring data that supported determination of the chlorophyll *a* criteria.

REFERENCE PHYTOPLANKTON COMMUNITIES AND WATER QUALITY CONDITION CLASSIFICATIONS

Season- and salinity-specific phytoplankton reference communities, and the water quality conditions required to maintain them, were derived from the 1985-1999 Chesapeake Bay Program monitoring data for waters that are the least affected by nutrients and poor water clarity (Buchanan et al., in review). Similarly, phytoplankton communities associated with excess nutrients, poor water clarity or both were described.

Analysis Approach

The Chesapeake Bay Monitoring Program has coordinated the year-round collection of plankton and water quality data at more than 26 stations for all salinity zones in the Chesapeake Bay mainstem and its major tidal tributaries since August 1984, although data for some parameters were collected over shorter periods of time (e.g., Virginia productivity measurements are available for 1989 to 1999). The primary data and data documentation are available at http://www.chesapeakebay.net/. Data records for individual station-date sampling events were sorted into two seasons and four salinity zones for examination: spring (March, April and May) and summer (July, August and September); and tidal fresh (0.0 to 0.5 ppt), oligohaline (>0.5 to 5.0 ppt), mesohaline (>5.0 to18.0 ppt) and polyhaline (>18.0 ppt). Water quality and phytoplankton data from the mixed upper layer of the water column (usually identified as "above-pycnocline," or AP) were analyzed, except for a few tidal-fresh stations where samples were collected from the whole water column (WC). Zooplankton are collected from the entire water column.

Data within each season-salinity group were binned (grouped) into 10 water quality categories defined by specific levels of light, dissolved inorganic nitrogen (DIN) and orthophosphate (PO_4), which are three critical environmental parameters for phytoplankton growth (Tables F-1 and F-2). "Poor" water quality conditions were characterized by low levels of light, *and* concentrations of DIN *and* PO_4 that exceed phytoplankton nutrient requirements. "Better" water quality conditions had high levels of light *and* limiting (low) concentrations of DIN *and* PO_4. Mixed water quality conditions (i.e., one or two water quality parameters qualified as Better but the other(s) did not) and extreme subsets of the Poor and Better categories (i.e., Worst and Best) were also investigated. The specific values of DIN and PO_4 dividing "Better" and "Poor" in Tables F-1 and F-2 were experimentally determined to be the nutrient limitation thresholds for natural Chesapeake Bay phytoplankton populations (Fisher et al. 1999). The specific values of Secchi depth dividing "Better" and "Poor" in Tables F-1 and F-2 were empirically determined

from the monitoring data to be the water clarity associated with the least impaired stations currently monitored in the Bay. They also are the light levels required for growth of underwater bay grasses.

Estimates of phytoplankton taxon biomasses were derived from the Maryland and Virginia Chesapeake Bay Monitoring Program phytoplankton count data (1984-1999) and used with other measured phytoplankton parameters to investigate phytoplankton communities across the range of water quality conditions currently experienced in the Chesapeake Bay.

Table F-1. Summer (July through September) classification criteria for Worst, Poor, Better and Best water quality categories. Key: Secchi, Secchi depth (meters); DIN, average dissolved organic nitrogen in surface mixed layer (mg liter^{-1}); PO4 (SRP), average orthophosphate in surface mixed layer (mg liter^{-1}); TF, tidal-fresh salinities (0 to 0.5 ppt); OH, oligohaline salinities (>0.5 to 5 ppt); MH, mesohaline salinties (>5 to 18 ppt); PH, polyhaline (>18 ppt.). The 25th%, median and 75th% of the parameter's values at stations identified as "good" by the Relative Status Method are given for comparison. See Buchanan et al. (in review) for details.

Parameter		Selected Summer Classification Criteria				Relative Status Method
		Worst	Poor	Better	Best	*25th%/median/75th%*
Secchi	TF	<0.6	=<0.8	>0.8	>1.0	*0.6 | 0.8 | 1.0*
Secchi	OH	<0.55	=<0.6	>0.6	>0.7	*0.55 | 0.6 | 0.7*
Secchi	MH	<1.2	=<1.45	>1.45	>1.7	*1.2 | 1.45 | 1.7*
Secchi	PH	<1.55	=<1.85	>1.85	>2.35	*1.55 | 1.85 | 2.35*
		Worst	Poor	Better	Best	*75th%/median/25th%*
DIN	TF	>.390	>0.070	=<0.070	<0.030	*.390 | .240 | .125*
DIN	OH	>.090	>0.070	=<0.070	<0.030	*.090 | .050 | .028*
DIN	MH	>.074	>0.070	=<0.070	<0.030	*.074 | .035 | .014*
DIN	PH	>.070	>0.070	=<0.070	<0.030	*.028 | .011 | .008*
		Worst	Poor	Better	Best	*75th%/median/25th%*
PO_4 (SRP)	TF	>0.025	>0.003	=<0.003	=<0.003	*.025 | .020 | .010*
PO_4 (SRP)	OH	>0.010	>0.003	=<0.003	=<0.003	*.010 | .009 | .004*
PO_4 (SRP)	MH	>0.008	>0.002	=<0.002	=<0.002	*.008 | .005 | .0035*
PO_4 (SRP)	PH	>0.010	>0.003	=<0.003	=<0.003	*.010 | .008 | .005*

Table F-2. Spring (March through May) criteria for Worst, Poor, Better and Best water quality categories. See Key: Secchi, Secchi depth (meters); DIN, average dissolved organic nitrogen in surface mixed layer (mg liter^{-1}); PO4 (SRP), average orthophosphate in surface mixed layer (mg liter^{-1}); TF, tidal fresh salinities (0 to 0.5 ppt); OH, oligohaline salinities (>0.5 to 5 ppt); MH, mesohaline salinities (>5 to 18 ppt); PH, polyhaline (>18 ppt.). The 25th%, median, and 75th% of the parameter's values at stations identified as "good" by the Relative Status Method are given for comparison. See Buchanan et al.(in review) for details.

Parameter		Selected Spring Classification Criteria				Relative Status Method
		Worst	Poor	Better	Best	*25th%/median/75th%*
Secchi	TF	<0.7	=<0.9	>0.9	>1.1	*0.7 | 0.9 | 1.10*
Secchi	OH	<0.5	=<0.7	>0.7	>1.1	*0.5 | 0.7 | 1.10*
Secchi	MH	<1.35	=<1.8	>1.8	>2.25	*1.35 | 1.80 | 2.25*
Secchi	PH	<1.6	=<2.15	>2.15	>2.55	*1.6 | 2.15 | 2.55*
		Worst	Poor	Better	Best	*75th%/median/25th%*
DIN	TF	>.585	>0.070	=<0.070	<0.030	*.585 | .434 | .290*
DIN	OH	>.885	>0.070	=<0.070	<0.030	*.885 | .680 | .464*
DIN	MH	>.265	>0.070	=<0.070	<0.030	*.265 | .150 | .070*
DIN	PH	>.070	>0.070	=<0.070	<0.030	*.063 | .020 | .011*
		Worst	Poor	Better	Best	*75th%/median/25th%*
PO_4 (SRP)	TF	>0.020	>0.003	=<0.003	=<0.003	*.020 | .136 | .010*
PO_4 (SRP)	OH	>0.010	>0.003	=<0.003	=<0.003	*.010 | .005 | .004*
PO_4 (SRP)	MH	>0.003	>0.002	=<0.002	=<0.002	*.003 | .002 | .0006*
PO_4 (SRP)	PH	>0.005	>0.003	=<0.003	=<0.003	*.005 | .004 | .0007*

Summary of Results

Chlorophyll *a*, productivity and pheophytin decline as water quality improves from Poor/Worst to Better/Best conditions. Relative proportions of the major taxonomic groups shift (e.g., diatoms replace dinoflagellates as biomass-dominants in the mesohaline), and abundances of key bloom-forming species decline as water quality improves. Spring and summer chlorophyll *a* concentrations are typically below 16 μg liter^{-1} in tidal fresh, 22.6 μg liter^{-1} in oligohaline, 26.8 μg liter^{-1} in mesohaline and 8.8 μg liter^{-1} in polyhaline (Table F-3). Light is particularly important in achieving the phytoplankton reference community. When light is above certain salinity- and season-specific levels, or thresholds, DIN and PO_4 can exceed phytoplankton growth-limiting concentrations to a point and not stimulate algal blooms. Below these light thresholds, average chlorophyll *a* cell content increases ("dark-adaptation") as does potential production rates and the likelihood of blooms.

Table F-3. Some characteristics of possible phytoplankton reference communities and their associated habitat conditions for DIN, PO_4 and light (measured as Secchi depth). Highlighted rows are the proposed phytoplankton reference communities for the Chesapeake Bay. Key: Chl, chlorophyll *a*; DIN, dissolved inorganic nitrogen; PO_4, phosphate; Range, 5th to 95th percentiles; 95th to 95th percentile; n, number of chlorophyll data points (number of productivity, taxa biomass and water quality data points are not always the same); Chloro, Chlorophytes; Chryso, Chrysophytes; Cyano, Cyanophytes or bluegreen algae; Other, other taxonomic groups, including the Cryptomonads; - , insufficient data (less than 10 data points); *, median and sometimes 95th% are artifacts of how below detection limit (BDL) values were dealt with. See Buchanan et al. (in review) for more details.

		Chlorophyll Median (Range)	**Productivity** Median (Range)	**Average Taxa Biomass** as Percent of Total Nano-Micro Phytoplankton Biomass						**Secchi Depth**	**DIN** Median (95th%)	**PO_4** Median (95th%)
	n	ug liter^{-1}	ug C liter^{-1} hour^{-1}	Chloro	Chryso	Cyano	Diatom	Dinoflag	Other	meters	mg liter^{-1}	mg liter^{-1}
SPRING Tidal Fresh												
Mixed_[better light]	15	8.3 (2.5 - 12.1)	34.5 (2.6 - 52.8)	8.78%	0.24%	0.91%	80.02%	2.87%	7.19%	>0.9	1.07 (2.024)	0.0086 (0.0215)
Secchi >0.7m	51	6.9 (2.3 - 16.5)	29.8 (1.5 - 167.9)	8.79%	0.52%	2.28%	79.35%	3.91%	5.15%	>0.7	1.168 (2.033)	0.0077 (0.02)
SPRING Oligohaline												
Mixed_[better light]	39	9.9 (3.6 - 22.5)	72.8 (14.1 - 173.9)	7.06%	0.28%	2.72%	54.29%	26.24%	9.40%	>0.7	0.915 (1.505)	0.0045 (0.0103)
Secchi >0.6m	45	9.6 (2.3 - 22.0)	64.5 (11.5 - 170.7)	7.01%	0.29%	3.41%	54.71%	24.94%	9.64%	>0.6	0.998 (1.509)	0.0051 (0.0144)
SPRING Mesohaline												
Better	10	6.0 (2.5 - 41.8)	-	0.05%	0.00%	0.02%	62.16%	35.90%	1.87%	>1.8	0.028 (0.07)	0.002 (0.002)*
Better AND Mixed_[better light]	127	5.7 (2.1 - 26.8)	13.5 (2.6 - 52.7)	0.22%	0.04%	0.17%	66.95%	27.57%	5.06%	>1.8	0.32 (0.67)	0.002 (0.0048)*
SPRING Polyhaline												
Best	11	2.3 (1.0 - 4.0)	-	0.36%	0.05%	0.03%	52.06%	42.68%	4.82%	>2.55	0.009 (0.014)	0.003 (0.003)*
Better	31	3.2 (1.0 - 7.0)	7.4 (1.2 - 16.1)	0.16%	0.01%	0.06%	43.35%	53.38%	3.03%	>2.15	0.01 (0.054)	0.003 (0.003)*
Better AND Mixed_[better light]	63	3.4 (0.8 - 7.6)	5.2 (1.0 - 16.2)	0.15%	0.02%	0.05%	43.41%	51.99%	4.37%	>2.15	0.02 (0.236)	0.003 (0.0077)*
SUMMER Tidal Fresh												
Mixed_[better light]	62	8.6 (3.3 - 16.0)	68.5 (12.0 - 121.8)	20.24%	0.33%	17.78%	39.83%	6.50%	15.32%	>0.8	0.928 (1.632)	0.004 (0.01)
Secchi >0.7m	76	8.6 (3.2 - 19.6)	109.5 (7.6 - 357.4)	20.11%	0.26%	20.21%	39.35%	7.26%	12.81%	>0.7	0.935 (1.665)	0.0045 (0.0105)
SUMMER Oligohaline												
Mixed_[better light]	65	6.4 (2.6 - 22.6)	57.1 (17.9 - 152.6)	8.82%	0.44%	10.98%	54.59%	14.25%	10.91%	>0.6	0.505 (0.959)	0.01 (0.045)
SUMMER Mesohaline												
Best	20	7.1 (4.9 - 14.3)	47.2 (11.3 - 84.7)	0.42%	0.93%	5.31%	58.32%	24.61%	10.42%	>1.7	0.01 (0.02)	0.0017 (0.002)*
Better	37	7.2 (4.9 - 16.2)	35.3 (6.0 - 86.3)	0.25%	0.50%	1.43%	57.87%	32.69%	7.26%	>1.45	0.01 (0.042)	0.0017 (0.002)*
Better AND Mixed_[better light]	200	7.1 (4.1 - 15.1)	55.4 (9.8 - 105.6)	0.66%	0.47%	3.41%	47.56%	39.38%	8.51%	>1.45	0.028 (0.18)	0.0041 (0.0184)
SUMMER Polyhaline												
Best	18	3.5 (0 - 6.8)	-	0.10%	0.03%	0.01%	50.72%	44.63%	4.52%	>2.35	0.01 (0.012)	0.003 (0.003)*
Better	39	4.4 (1.5 - 8.8)	10.2 (3.4 - 34.6)	0.14%	0.11%	0.10%	44.26%	50.53%	4.86%	>1.85	0.01 (0.031)	0.003 (0.003)*
Better AND Mixed_[better light]	109	4.1 (0.2 - 9.5)	9.0 (2.0 - 33.5)	0.68%	0.07%	0.06%	42.31%	43.41%	13.47%	>1.85	0.01 (0.07)	0.008 (0.02)

LITERATURE CITED

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Fisher, T. R., L. W. Harding, D. W. Stanley and L. G. Ward. 1988. Phytoplankton, nutrients and turbidity in the Chesapeake, Delaware and Hudson estuaries. *Estuarine, Coastal and Shelf Science* 27:61-93.